

APPENDIX B

OLIGOHALINE ZONE LITERATURE REVIEW

REPORT

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INTRODUCTION

The oligohaline, or low salinity, region of an estuary occurs where fresh and saline waters meet. The oligohaline salinity range is typically defined as 0.5 to 5.0 parts per thousand (ppt) (Day et al., 1989), although some studies extend the range to 10 ppt (Coastal Environmental, 1992; Peterson, 1991; Holmes et al., 2000). In contrast to the higher salinity portions of estuaries, relatively few studies have focused on the oligohaline zone (Hackney and de la Cruz, 1981; Hastings et al., 1987; Rozas and Odum, 1987; Odum, 1988; LaSalle and Bishop, 1990; Wagner and Austin, 1999; Holmes et al., 2000; Hughes et al., 2000). No studies are known that detail the functions of the oligohaline zone(s) of the St. Lucie Estuary. However, several studies have identified fish species that occur in low salinity portions of the estuary (Gunter and Hall, 1963; Haunert and Startzman, 1980, 1985).

The purpose of this report is to summarize available literature regarding the importance of oligohaline zones in estuaries to assist with development of minimum flows and levels criteria for the St. Lucie Estuary. The studies reviewed generally characterize the oligohaline zone as a physically demanding, dynamic, and highly productive area. These studies suggest processes that occur in this zone are important to overall estuarine ecosystem health. This report summarizes 1) some important physical, chemical, and biological processes that occur in the oligohaline zone; 2) the role of the oligohaline zone as a buffer to downstream waters; and 3) the habitat/nursery value of the oligohaline zone.

PHYSICAL, CHEMICAL, AND BIOLOGICAL PROCESSES

Freshwater inflow to estuaries determines the size and position of the oligohaline zone. Because estuarine inflows are typically variable, the size and position of the oligohaline are variable. The physically dynamic nature of the oligohaline zone, dramatic ionic changes that occur at very low salinities (probably between 1 and 2 ppt) (Deaton and Greenberg, 1986), and high turbidity often associated with this region (Sin et al., 1999) make it a difficult place for organisms to live. Few species have adapted to low salinity environments (Remane and Schlieper, 1971). However, those species able to survive these harsh conditions have the advantage of reduced competition, few predators/disease, and abundant food supply (Rozas and Hackney, 1983; Browder, 1991). These factors may be what attracts some organisms to the oligohaline zone, rather than a specific salinity range (Rozas and Hackney, 1984; Livingston, 1997).

The abundant food supply associated with oligohaline zones is largely due to the nutrients associated with freshwater inflow. These nutrients support phytoplankton growth that can form the base of an extensive estuarine food chain (Hughes et al., 2000). In order for the nutrients to be available for phytoplankton growth within the oligohaline zone, appropriate freshwater discharge rates are needed. Since freshwater discharge rates affect residence time, nutrient input, light regime, and tidal mixing, they can regulate the magnitude, location, and timing of primary production in an estuary (Sin et al., 1999). If discharge is too high the nutrients and/or phytoplankton may be flushed downstream (Holmes et al., 2000) and organisms that depend on this food source may have to leave the “refuge” (few predators, less competition) of the oligohaline zone to take advantage of other food supplies. This could affect community structure throughout the estuary and its receiving waters.

Additionally, important transformations of nutrients occur in the upper estuary (Alpine and Cloern, 1992; Holmes et al., 2000). The processing of nutrients in the oligohaline zone is an important function that can influence energy transported throughout the estuary. Holmes et al. (2000) and Hughes et al. (2000) found that all watershed-derived dissolved inorganic nitrogen was rapidly processed in the oligohaline zone during low flow conditions in the Parker River Estuary in Massachusetts. They indicated that this highlights the importance of the oligohaline zone to the nitrogen cycle of the entire estuary.

Anderson (1986), studying three subestuaries of the Chesapeake Bay, found that freshwater diatoms depleted dissolved reactive silica, a critical nutrient for diatom growth, in the water column before the freshwater flow reached the oligohaline zone. Despite this depletion, he found that dissolved reactive silica levels increased in the oligohaline zone. He suggested that this increase may be a result of the lysing of diatom cells in response to the rapid salinity change in the oligohaline zone. Anderson suggests that this process accelerates remineralization of silica (and probably nitrogen and phosphorus) into the estuary and points to the importance of the oligohaline zone in the cycling of silica.

BUFFER

The processing of nutrients, discussed above, as well as other chemical, physical, and biological transformations in the oligohaline zone (Morris et al., 1978) affect the material and energy transported downstream to the estuary and, ultimately, the ocean. Therefore, Holmes et al. (2000) suggest that the oligohaline zone can be considered an important “buffer or ecotone” between the watershed and the lower estuary and the ocean. Odum et al. (1984) suggested that because of its intermediate position between coastal waters and fresh waters, pollutants (heavy metals, nutrients, suspended solids, etc.) from upstream may be partially intercepted and processed in low salinity areas. In this regard, the oligohaline zone may act as a filter effectively improving the health of downstream habitats.

HABITAT VALUE

Most of the studies reviewed focused on the habitat value of the oligohaline zone. It is apparent that low salinity waters in the upper estuary are critical to the life histories of many estuarine organisms (Holmes et al., 2000; Hughes et al., 2000). A summary of the habitat and/or nursery functions of the oligohaline zone for a wide variety of organisms is presented below.

Micro Invertebrates

As discussed above, the freshwater inflow brings with it nutrients that are used by phytoplankton. The phytoplankton then becomes food for zooplankton such as copepods. In an oligohaline study conducted by Hughes et al. (2000), the most important oligohaline planktonic primary consumer was the copepod, *Eurytemora affinis*, which is found ubiquitously in low salinity waters of North America. This particular copepod appears to mature in the oligohaline zone; consuming diatoms and detritus. Holmes et al. (2000) suspect that a similar trophic structure occurs in the oligohaline zone of other estuaries that support phytoplankton blooms.

Macro Invertebrates

The oligohaline zone provides habitat for numerous macro invertebrates. Boesch and Diaz (1974) found that peracarids (amphipods, isopods, etc.) were more diverse than most other invertebrate groups in oligohaline environments and were probably ecologically important in this zone. Dauvin et al. (2000) reported decapods and peracarids dominate the water column near the bottom of the English Channel forming a direct link between the benthos and the pelagos because of daily vertical and horizontal migrations. In the Seine Estuary, Dauvin et al. (2000) found that biomass of suprabenthic hauls were very high, especially in the mesohaline and oligohaline zones where mysids were abundant.

Other studies focused on the use of the oligohaline zone by barnacles and mollusks. Poirrier and Partridge (1979) studied an oligohaline barnacle, *Balanus subalbidus*, which is reported from estuaries on the East Coast of the United States (including Florida). It is an apparent indicator species of low salinity environments because densities of this organism quickly drop off at salinities above 6 ppt. Another study pointed to the abundance of gastropods and bivalves in poorly flooded oligohaline marshes (Bishop and Hackney, 1987). One specific bivalve, *Rangia cuneata*, grew to greatest size in very low salinity habitats (Gunter, 1961).

Larval Insects

Oligohaline marshes support abundant populations of larval insects, particularly dipteran species (Menzie, 1980; LaSalle and Bishop, 1987, 1990). LaSalle and Bishop (1987, 1990) suggest that low salinity marsh habitats support a larger number of larval

insect species than higher salinity areas. Diptera in oligohaline marshes consume oligochaetes, nematodes, and polychaetes, which primarily feed on the microbial-detritus complex (LaSalle and Bishop, 1987, 1990). The larval insects are in turn consumed by aquatic predators such as fish. Additionally, when the insects emerge from their aquatic habitat as adults, they provide an important pathway of energy (biomass) flow into terrestrial ecosystems. Larval insect fauna in oligohaline zones may contribute importantly to the trophic dynamics of estuarine systems (Menzie, 1980).

Fisheries

Most of the habitat studies reviewed focused on the use of the oligohaline zone by fish. Many of the species of fish inhabiting the oligohaline zone support economically important commercial and sport fisheries (Rozas and Hackney, 1983; Day et al., 1989; Edwards, 1992). **Table B-1** provides a list of fish species identified through this literature review that use the oligohaline zone for some part of their life history. The oligohaline zone supports freshwater, estuarine, and marine fishes (Rozas and Hackney, 1983; Odum et al., 1988; Peterson and Ross, 1991). However, marine and estuarine species numerically dominate the oligohaline fauna (Gunter, 1956).

Although the vast majority of fish found in the oligohaline zone are juveniles, several studies pointed to the use of the oligohaline zone by adult fish for spawning and feeding. Striped bass (*Morone saxatilis*), an important commercial and sport fish, is known to spawn and feed in oligohaline and fresh waters (Rozas and Hackney, 1983; Odum et al., 1984). Freshwater species observed spawning in oligohaline waters include bluegill (*Lepomis macrochirus*) and largemouth bass (*Micropterus salmoides*) (Rozas and Hackney, 1983). Only a few fish are known to be true residents of the oligohaline zone (mosquito fish, *Gambusia affinis*; tidewater silversides, *Menidia beryllina*; and grass shrimp, *Palaemonetes pugio*) (Rozas and Hackney, 1984). In addition to finfish, blue crabs (*Calinectes sapidus*), especially adult males, are known to feed in oligohaline waters (Rozas and Hackney, 1983).

The vast majority of the oligohaline fisheries literature focused on the use of this zone as a nursery (Gunter, 1961; Weinstein, 1979; Day et al., 1981; Rogers et al., 1984; Rozas and Hackney, 1983, 1984; Deegan and Thompson, 1985; Ross and Epperly, 1985; Felley, 1987; Browder, 1991; Peterson and Ross, 1991; Coastal Environmental, 1992; Deegan and Garritt, 1997; Wagner and Austin, 1999). In general, smaller and younger fish initially distribute themselves in lower salinity water and migrate towards the sea as they grow larger (Gunter, 1961). At least some juvenile fish have lengthy stays in the oligohaline zone. Deegan and Garritt (1997) found that some fish stay in the oligohaline zone from the spring through the summer. Weinstein (1979) found that some species remain in the oligohaline zone from winter through fall. For at least one species, the Atlantic menhaden (*Brevoortia tyrannus*), the oligohaline zone may be essential for development into juveniles (Rozas and Hackney, 1984).

Table B-1. A Partial List of Fish and Shellfish Collected in Oligohaline Waters

Scientific Name	Common Name	Size Class			Location	Reference
		Adult	Juvenile	Not Specified		
<i>Achirus lineatus</i> ^a	Lined sole			✓	St. Louis Bay, Missouri	Hackney and de la Cruz, 1981
<i>Adinia xenica</i>	Diamond killifish			✓	St. Louis Bay, Missouri	Hackney and de la Cruz, 1981
<i>Albula vulpes</i> ^a	Bonefish		✓		St. Lucie River, Florida	Haunert and Startzman, 1985
<i>Alosa aestivalis</i>	Blueback herring			✓	North Carolina	Rozas and Hackney, 1984
<i>Alosa alabamae</i>	Alabama shad			✓	Lake Maurepas, Louisiana	Hastings et al., 1987
<i>Alosa chysochloris</i>	Skipjack herring			✓	Lake Maurepas, Louisiana	Hastings et al., 1987
<i>Alosa pseudoharengus</i>	Alewife		✓		Parker River Estuary, Massachusetts	Hughes et al., 2000
<i>Amia calva</i>	Bowfin			✓	Lake Maurepas, Louisiana	Hastings et al., 1987
<i>Anguilla rostrata</i>	American eel			✓	Lake Maurepas, Louisiana Parker River Estuary, Massachusetts	Hastings et al., 1987 Hughes et al., 2000
<i>Anchoa mitchilli</i> ^a	Bay Anchovy	✓	✓		Not specified St. Lucie River, Florida York River, Virginia Barataria Basin, Louisiana St. Louis Bay, Missouri North Carolina Calcasieu Estuary, Louisiana Lake Maurepas, Louisiana Old Fort Bayou, Missouri Little Manatee River, Florida	Gunter, 1961 Gunter and Hall, 1963 Markle, 1976 Day et al., 1981 Hackney and de la Cruz, 1981 Rozas and Hackney, 1984 Felley, 1987 Hastings et al., 1987 Peterson and Ross, 1991 Edwards, 1992
<i>Apeltes quadracus</i>	Four-spined stickleback			✓	Parker River Estuary, Massachusetts	Hughes et al., 2000
<i>Aphredoderus sayanus</i>	Pirate perch			✓	Lake Maurepas, Louisiana	Hastings et al., 1987
<i>Aplodinotus grunniens</i>	Freshwater drum			✓	Lake Maurepas, Louisiana	Hastings et al., 1987
<i>Archosargus probatocephalus</i> ^a	Sheepshead			✓	Lake Maurepas, Louisiana	Hastings et al., 1987
<i>Arius felis</i> ^a	Hardhead catfish			✓	Lake Maurepas, Louisiana Little Manatee River, Florida	Hastings et al., 1987 Edwards, 1992
<i>Astroscoptes sp.</i>	Stargazer			✓	North Carolina	Rozas and Hackney, 1984
<i>Bagre marinus</i> ^a	Gafftopsail catfish			✓	Lake Maurepas, Louisiana	Hastings et al., 1987
<i>Bairdiella chrysoura</i> ^a	Silver perch			✓	York River, Virginia North Carolina	Markle, 1976 Rozas and Hackney, 1984
<i>Brevoortia patronus</i>	Gulf menhaden		✓		Grand and White Lakes, Louisiana Calcasieu Estuary, Louisiana Lake Maurepas, Louisiana Old Fort Bayou, Missouri	Gunter, 1961 Felley, 1987 Hastings et al., 1987 Peterson and Ross, 1991
<i>Brevoortia smithii</i> ^a	Fine-scale menhaden		✓		St. Lucie River, Florida	Gunter and Hall, 1963
<i>Brevoortia tyrannus</i> ^a	Atlantic menhaden		✓		North Carolina	Rozas and Hackney, 1984

a. Species found in the St. Lucie Estuary (Gunter and Hall, 1963; Haunert and Startzman, 1980, 1985)

Table B-1. A Partial List of Fish and Shellfish Collected in Oligohaline Waters (Continued)

Scientific Name	Common Name	Size Class			Location	Reference
		Adult	Juvenile	Not Specified		
<i>Callinectes sapidus</i> ^a	Blue crab	✓	✓		Grand and White Lakes, Louisiana Barataria Basin, Louisiana St. Louis Bay, Missouri	Gunter, 1961 Day et al., 1981 Hackney and de la Cruz, 1981
<i>Caranx hippos</i> ^a	Crevalle jack			✓	Lake Maurepas, Louisiana	Hastings et al., 1987
<i>Carpoides carpio</i>	River carpsucker			✓	Lake Maurepas, Louisiana	Hastings et al., 1987
<i>Catostomus commersoni</i>	White sucker		✓		Parker River Estuary, Massachusetts	Hughes et al., 2000
<i>Centropomus undecimalis</i> ^a	Snook		✓		St. Lucie River, Florida Indian River Lagoon, Florida Little Manatee River, Florida	Gunter and Hall, 1963 Haunert and Startzman, 1980, 1985 Peterson and Gilmore, 1991 Edwards, 1992
<i>Citharichthys spilopterus</i> ^a	Bay whiff			✓	Lake Maurepas, Louisiana	Hastings et al., 1987
<i>Crangon septemspinosa</i>	Sand shrimp			✓	Parker River Estuary, Massachusetts	Hughes et al., 2000
<i>Cynoscion arenarius</i>	Sand seatrout			✓	Lake Maurepas, Louisiana	Hastings et al., 1987
<i>Cynoscion nebulosus</i> ^a	Spotted seatrout	✓	✓		St. Louis Bay, Missouri Little Manatee River, Florida	Hackney and de la Cruz, 1981 Edwards, 1992
<i>Cynoscion regalis</i> ^a	Weakfish			✓	York River, Virginia	Markle, 1976
<i>Cyprinodon variegatus</i> ^a	Sheepshead minnow			✓	Lake Maurepas, Louisiana	Hastings et al., 1987
<i>Cyprinus carpio</i>	Common carp			✓	Lake Maurepas, Louisiana	Hastings et al., 1987
<i>Dasyatis sabina</i> ^a	Atlantic stingray			✓	Lake Maurepas, Louisiana	Hastings et al., 1987
<i>Diapterus olisthostomus</i> ^a	Sand perch			✓	St. Lucie River, Florida	Gunter and Hall, 1963
<i>Diapterus plumieri</i> ^a	Striped mojarra			✓	Little Manatee River, Florida	Edwards, 1992
<i>Dormitor maculatus</i>	Fat Sleeper			✓	North Carolina	Rozas and Hackney, 1984
<i>Dorosoma cepedianum</i> ^a	Gizzard shad			✓	North Carolina St. Lucie River, Florida Lake Maurepas, Louisiana	Rozas and Hackney, 1984; Haunert and Startzman, 1985 Hastings et al., 1987
<i>Dorosoma petenense</i> ^a	Threadfin shad			✓	Lake Maurepas, Louisiana	Hastings et al., 1987
<i>Elassoma zonatum</i>	Banded pygmy sunfish			✓	Lake Maurepas, Louisiana	Hastings et al., 1987
<i>Eleotris pisonis</i>	Spinycheek Sleeper			✓	North Carolina	Rozas and Hackney, 1984
<i>Elops saurus</i> ^a	Ladyfish		✓	✓	James River, Virginia St. Lucie River, Florida Lake Maurepas, Louisiana	Govoni and Merriner, 1978 Haunert and Startzman, 1985 Hastings et al., 1987
<i>Enneacanthus gloriosus</i> ^a	Bluespotted sunfish			✓	Atlantic Coast	Rozas and Hackney, 1983 citing Raney and Massmann, 1953
<i>Esox niger</i>	Chain pickerel			✓	Parker River Estuary, Massachusetts	Hughes et al., 2000
<i>Eucinostomus juveniles</i> ^a	Mojarra		✓		Little Manatee River, Florida	Edwards, 1992

a. Species found in the St. Lucie Estuary (Gunter and Hall, 1963; Haunert and Startzman, 1980, 1985)

Table B-1. A Partial List of Fish and Shellfish Collected in Oligohaline Waters (Continued)

Scientific Name	Common Name	Size Class			Location	Reference
		Adult	Juvenile	Not Specified		
<i>Eucinostomus argenteus</i> ^a	Spotfin mojarra			✓	St. Lucie River, Florida	Gunter and Hall, 1963
<i>Eucinostomus lefroyi</i>	Mottled mojarra			✓	North Carolina	Rozas and Hackney, 1984
<i>Evorthodus lyricus</i> ^a	Lyre goby			✓	St. Louis Bay, Missouri North Carolina	Hackney and de la Cruz, 1981 Rozas and Hackney, 1984
<i>Fundulus chrysotus</i>	Golden topminnow			✓	Gulf Coast Lake Maurepas, Louisiana	Hastings et al., 1987
<i>Fundulus confluentus</i> ^a	Marsh killifish			✓	St. Louis Bay, Missouri	Hackney and de la Cruz, 1981
<i>Fundulus diaphanus</i>	Banded killifish			✓	Parker River Estuary, Massachusetts	Hughes et al., 2000
<i>Fundulus grandis</i> ^a	Gulf killifish			✓	St. Louis Bay, Missouri Lake Maurepas, Louisiana	Hackney and de la Cruz, 1981 Hastings et al., 1987
<i>Fundulus heteroclitus</i>	Mummichog			✓	North Carolina Plum Island Sound, Massachusetts Parker River Estuary, Massachusetts.	Rozas and Hackney, 1984 Deegan and Garritt, 1997 Hughes et al., 2000
<i>Fundulus jenkinsi</i>	Saltmarsh topminnow			✓	Old Fort Bayou, Missouri	Peterson and Ross, 1991
<i>Fundulus luciae</i>	Spotfin killifish			✓	North Carolina	Rozas and Hackney, 1984
<i>Fundulus pulvereus</i>	Bayou killifish			✓	Lake Maurepas, Louisiana Old Fort Bayou, Missouri	Hastings et al., 1987 Peterson and Ross, 1991
<i>Fundulus seminolis</i> ^a	Seminole killifish			✓	Little Manatee River, Florida	Edwards, 1992
<i>Galeichthys felis</i> ^a	Sea catfish	✓	✓		St. Lucie River, Florida	Gunter and Hall, 1963
<i>Gambusia affinis</i> ^a	Mosquitofish	✓	✓		St. Lucie River, Florida North Carolina St. Lucie River, Florida Lake Maurepas, Louisiana Little Manatee River, Florida	Gunter and Hall, 1963 Rozas and Hackney, 1984 Haunert and Startzman, 1985 Hastings et al., 1987 Edwards, 1992
<i>Gobionellus boleosoma</i> ^a	Darter goby			✓	St. Lucie River, Florida	Gunter and Hall, 1963
<i>Gobionellus hastatus</i> ^a	Sharptail goby			✓	North Carolina	Rozas and Hackney, 1984
<i>Gobionellus shufeldti</i>	Freshwater goby			✓	North Carolina Lake Maurepas, Louisiana	Rozas and Hackney, 1984 Hastings et al., 1987
<i>Gobiosoma bosc</i> ^a	Naked goby			✓	St. Louis Bay, Missouri Lake Maurepas, Louisiana	Hackney and de la Cruz, 1981 Hastings et al., 1987
<i>Heterandria formosa</i> ^a	Least killifish			✓	St. Lucie River, Florida Lake Maurepas, Louisiana	Gunter and Hall, 1963; Hastings et al., 1987
<i>Ictalurus catus</i> ^a	White catfish	✓	✓		St. Lucie River, Florida York River, Virginia North Carolina St. Lucie River, Florida	Gunter and Hall, 1963 Markle, 1976 Rozas and Hackney, 1984 Haunert and Startzman, 1985
<i>Ictalurus furcatus</i>	Blue catfish			✓	Lake Maurepas Louisiana	Hastings et al., 1987
<i>Ictalurus melas</i>	Black bullhead			✓	Lake Maurepas, Louisiana	Hastings et al., 1987
<i>Ictalurus natalis</i>	Yellow bullhead			✓	Lake Maurepas, Louisiana	Hastings et al., 1987

a. Species found in the St. Lucie Estuary (Gunter and Hall, 1963; Haunert and Startzman, 1980, 1985)

Table B-1. A Partial List of Fish and Shellfish Collected in Oligohaline Waters (Continued)

Scientific Name	Common Name	Size Class			Location	Reference
		Adult	Juvenile	Not Specified		
<i>Ictalurus nebulosus</i> ^a	Brown bullhead			✓	St. Lucie River, Florida	Gunter and Hall, 1963
<i>Ictalurus punctatus</i> ^a	Channel catfish			✓	York River, Virginia Lake Maurepas, Louisiana	Markle, 1976 Hastings et al., 1987
<i>Ictiobus bubalus</i>	Smallmouth buffalo			✓	Lake Maurepas, Louisiana	Hastings et al., 1987
<i>Labidesthes sicculus</i>	Brook silverside			✓	Lake Maurepas, Louisiana	Hastings et al., 1987
<i>Lagodon rhomboides</i> ^a	Pinfish			✓	North Carolina Little Manatee River, Florida	Rozas and Hackney, 1984 Edwards, 1992
<i>Leiostomus xanthurus</i> ^a	Spot			✓	York River, Virginia North Carolina Lake Maurepas, Louisiana Little Manatee River, Florida	Markle, 1976 Rozas and Hackney, 1984 Hastings et al., 1987 Edwards, 1992
<i>Lepisosteus oculatus</i>	Spotted gar			✓	Lake Maurepas, Louisiana	Hastings et al., 1987
<i>Lepisosteus osseus</i>	Longnose gar			✓	North Carolina Lake Maurepas, Louisiana	Rozas and Hackney, 1984; Hastings et al., 1987
<i>Lepisosteus spatula</i>	Alligator Gar			✓	Lake Maurepas, Louisiana	Hastings et al., 1987
<i>Lepomis gibbosus</i>	Pumpkinseed	✓	✓		North Carolina	Rozas and Hackney, 1984
<i>Lepomis gulosus</i>	Warmouth			✓	Lake Maurepas, Louisiana	Hastings et al., 1987
<i>Lepomis macrochirus</i> ^a	Bluegill	✓	✓		St. Louis Bay, Missouri Lake Maurepas, Louisiana Little Manatee River, Florida Plum Island Sound, Massachusetts.	Hackney and de la Cruz, 1981 Hastings et al., 1987 Edwards, 1992 Deegan and Garritt, 1997
<i>Lepomis meglotis</i>	Longear sunfish			✓	Lake Maurepas, Louisiana	Hastings et al., 1987
<i>Lepomis microlophus</i> ^a	Redear sunfish			✓	Lake Maurepas, Louisiana	Hastings et al., 1987
<i>Lepomis punctatus</i>	Spotted sunfish			✓	Lake Maurepas, Louisiana	Hastings et al., 1987
<i>Lepomis symmetricus</i>	Bantam sunfish			✓	Lake Maurepas, Louisiana	Hastings et al., 1987
<i>Lucania parva</i> ^a	Rainwater killifish			✓	St. Louis Bay, Missouri Lake Maurepas, Louisiana Little Manatee River, Florida	Hackney and de la Cruz, 1981 Hastings et al., 1987 Edwards, 1992
<i>Lutjanus griseus</i> ^a	Gray snapper			✓	St. Lucie River, Florida	Gunter and Hall, 1963
<i>Megalops atlanticus</i> ^a	Tarpon		✓		St. Lucie River, Florida	Haunert and Startzman, 1985
<i>Membras martinica</i> ^a	Rough silverside			✓	St. Louis Bay, Missouri	Hackney and de la Cruz, 1981
<i>Menidia beryllina</i> ^a	Inland or tidewater silverside			✓	North Carolina Calcasieu Estuary, Louisiana Lake Maurepas, Louisiana Old Fort Bayou, Missouri Little Manatee River, Florida	Rozas and Hackney, 1984 Felley, 1987 Hastings et al., 1987 Peterson and Ross, 1991 Edwards, 1992
<i>Menidia menidia</i> ^a	Atlantic silverside			✓	Plum Island Sound, Massachusetts Parker River Estuary, Massachusetts	Deegan and Garritt, 1997 Hughes et al., 2000
<i>Microgobius gulosus</i> ^a	Clown goby			✓	Lake Maurepas, Louisiana	Hastings et al., 1987

a. Species found in the St. Lucie Estuary (Gunter and Hall, 1963; Haunert and Startzman, 1980, 1985)

Table B-1. A Partial List of Fish and Shellfish Collected in Oligohaline Waters (Continued)

Scientific Name	Common Name	Size Class			Location	Reference
		Adult	Juvenile	Not Specified		
<i>Micropogonias undulatus</i> ^a	Atlantic croaker	✓	✓		Grand and White Lakes, Louisiana York River, Virginia Upper Barataria Basin, Louisiana North Carolina Lake Maurepas, Louisiana	Gunter, 1961 Markle, 1976 Day et al., 1981 Rozas and Hackney, 1984 Hastings et al., 1987
<i>Micropterus salmoides</i> ^a	Largemouth bass	✓	✓		St. Louis Bay, Missouri North Carolina Lake Maurepas, Louisiana	Hackney and de la Cruz, 1981 Rozas and Hackney, 1984 Hastings et al., 1987
<i>Morone americana</i>	White perch			✓	York River, Virginia Plum Island Sound, Missouri	Markle, 1976 Deegan and Garritt, 1997
<i>Morone chrysops</i>	White bass			✓	Lake Maurepas, Louisiana	Hastings et al., 1987
<i>Morone mississippiensis</i>	Yellow bass			✓	Lake Maurepas, Louisiana	Hastings et al., 1987
<i>Morone saxatilis</i>	Striped bass	✓	✓	✓	York River, Virginia North Carolina Lake Maurepas, Louisiana	Markle, 1976 Rozas and Hackney, 1984 Hastings et al., 1987
<i>Mugil cephalus</i> ^a	Striped mullet ^a		✓	✓	St. Lucie River, Florida St. Louis Bay, Missouri North Carolina Lake Maurepas, Louisiana Little Manatee River, Florida	Haunert and Starzman, 1980 Hackney and de la Cruz, 1981 Rozas and Hackney, 1984 Hastings et al., 1987 Edwards, 1992
<i>Mugil curema</i> ^a	Silver mullet ^a		✓		St. Lucie River, Florida	Gunter and Hall, 1963
<i>Myrophis punctatus</i>	Speckled worm eel			✓	North Carolina Lake Maurepas, Louisiana	Rozas and Hackney, 1984 Hastings et al., 1987
<i>Notemigonus crysoleucas</i>	Golden shiner			✓	St. Lucie River, Florida	Hughes et al., 2000
<i>Notemigonus crysoleucas</i> ^a	Golden shiner			✓	Lake Maurepas, Louisiana	Hastings et al., 1987
<i>Notropis emiliae</i>	Pugnose minnow			✓	Lake Maurepas, Louisiana	Hastings et al., 1987
<i>Notropis petersonii</i>	Coastal shiner			✓	Old Fort Bayou, Missouri	Peterson and Ross, 1991
<i>Noturus gyrinus</i>	Tadpole madtom			✓	Lake Maurepas, Louisiana	Hastings et al., 1987
<i>Oligoplites saurus</i> ^a	Leatherjacket			✓	St. Louis Bay, Missouri	Hackney and de la Cruz, 1981
<i>Osmerus mordax</i>	Rainbow smelt			✓	Parker River Estuary, Massachusetts	Hughes et al., 2000
<i>Palaemonetes bulgaris</i>	Grass shrimp			✓	Parker River Estuary, Massachusetts	Hughes et al., 2000
<i>Palaemonetes pugio</i>	Grass shrimp	✓	✓		St. Louis Bay, Missouri North Carolina	Hackney and de la Cruz, 1981 Rozas and Hackney, 1984
<i>Paralichthys lethostigma</i>	Southern flounder		✓		North Carolina Calcasieu Estuary, Louisiana Lake Maurepas, Louisiana	Rozas and Hackney, 1984 Felley, 1987 Hastings et al., 1987
<i>Farfantepenaeus aztecus</i> ^a	Brown shrimp	✓	✓		Grand and White Lakes, Louisiana St. Lucie River, Florida Old Fort Bayou, Missouri	Gunter, 1961 Peterson and Ross, 1991

a. Species found in the St. Lucie Estuary (Gunter and Hall, 1963; Haunert and Startzman, 1980, 1985)

Table B-1. A Partial List of Fish and Shellfish Collected in Oligohaline Waters (Continued)

Scientific Name	Common Name	Size Class			Location	Reference
		Adult	Juvenile	Not Specified		
<i>Farfantepenaeus setiferus</i>	White shrimp		✓	✓	Grand and White Lakes, Louisiana Calcasieu Estuary, Louisiana Old Fort Bayou, Missouri	Gunter, 1961 Gunter and Hall, 1963 Felley, 1987 Peterson and Ross, 1991
<i>Petromyzon marinus</i>	Sea lamprey		✓		Parker River Estuary, Massachusetts	Hughes et al., 2000
<i>Pleuronectes americanus</i>	Winter flounder		✓		Plum Island Sound, Missouri	Deegan and Garritt, 1997
<i>Poecilia latipinna</i> ^a	Sailfin molley		✓		Little Manatee River, Florida	Edwards, 1992
<i>Pogonias cromis</i> ^a	Black drum		✓		Lake Maurepas, Louisiana	Hastings et al., 1987
<i>Polyodon spathula</i>	Paddlefish		✓		Lake Maurepas, Louisiana	Hastings et al., 1987
<i>Pomatomus saltatrix</i> ^a	Bluefish		✓		North Carolina Plum Island Sound, Missouri	Rozas and Hackney, 1984 Deegan and Garritt, 1997
<i>Pomoxis annularis</i>	White crappie		✓		Lake Maurepas, Louisiana	Hastings et al., 1987
<i>Pomoxis nigromaculatus</i> ^a	Black crappie		✓		North Carolina St. Lucie River, Florida Lake Maurepas, Louisiana	Rozas and Hackney, 1984 Haunert and Startzman, 1985; Hastings et al., 1987
<i>Pungitius pungitius</i>	Nine-spined stickleback		✓		Parker River Estuary, Massachusetts	Hughes et al., 2000
<i>Pylodictus olivaris</i>	Flathead catfish		✓		Lake Maurepas, Louisiana	Hastings et al., 1987
<i>Sciaenops ocellatus</i> ^a	Red drum	✓	✓		St. Lucie River, Florida Little Manatee River, Florida	Haunert and Startzman, 1980 Edwards, 1992
<i>Strongylura marina</i> ^a	Atlantic needlefish		✓		North Carolina Lake Maurepas, Louisiana	Rozas and Hackney, 1984 Hastings et al., 1987
<i>Syngnathus scovelli</i> ^a	Gulf pipefish		✓		Lake Maurepas, Louisiana	Hastings et al., 1987
<i>Symphurus plagiusa</i> ^a	Blackcheek tonguefish		✓		Gulf and Atlantic Coasts	Rozas and Hackney, 1983 citing Rounsefell, 1964
<i>Syngnathus fuscus</i>	Northern pipefish		✓		Parker River Estuary, Massachusetts	Hughes et al., 2000
<i>Syngnathus louisianae</i> ^a	Chain pipefish		✓		Gulf Coast	Rozas and Hackney, 1983 citing Dahlberg, 1972
<i>Synodus foetens</i> ^a	Inshore lizardfish		✓		Gulf Coast	Rozas and Hackney, 1983 citing Dahlberg, 1972
<i>Trinectes maculatus</i> ^a	Hogchoker		✓		Grand and White Lakes, Louisiana York River, Virginia Lake Maurepas, Louisiana Little Manatee River, Florida	Gunter, 1961 Markle, 1976 Hastings et al., 1987 Edwards, 1992

a. Species found in the St. Lucie Estuary (Gunter and Hall, 1963; Haunert and Startzman, 1980, 1985)

DISCUSSION

Although studies of the oligohaline zone of estuaries are limited, it is clear that the oligohaline zone is an important estuarine region and that maximizing this zone in an estuary will benefit the estuarine ecology. Physical, chemical, and biological processes in the oligohaline zone are important to estuarine primary productivity and provide a unique habitat and refuge for numerous organisms. The oligohaline zone also acts as a buffer, ecotone, and filter between tidal freshwater areas and downstream estuarine habitats. Additionally, the oligohaline zone provides habitat, including nursery areas, for numerous freshwater, estuarine, and marine organisms.

Although studies specific to the St. Lucie Estuary oligohaline zone(s) have not yet been conducted, it is reasonable to expect that the functions described above for other estuaries would be provided in the oligohaline reaches of this estuary. For example, numerous fish species found in the St. Lucie Estuary (**Table B-1**) are known to occur in oligohaline regions. Restoration and maintenance of a healthy, productive oligohaline zone would benefit these fish species as well as numerous other organisms. Ultimately this should improve sport and commercial fisheries in the area.

Through the minimum flows and levels criteria development process for the St. Lucie Estuary, decisions will be made on the appropriate size and location of the oligohaline zone. The location and size of this zone will be dictated by freshwater inflow. Optimizing the oligohaline zone will require maximizing the overlap of favorable bottom and shoreline features with appropriate salinity ranges (Browder, 1991; Jassby et al., 1995). Maintaining a healthy oligohaline zone will be an important step toward successful restoration and maintenance of the St. Lucie Estuary.

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